

As stated above, Rayleigh's theory requires that the ratio of the intensity of the reflected ray to that of the incident ray shall vary as the fourth power of the wave-length, while Crova's measurements gave exponents varying between 1.61 and 6.44. From this fact, and further, since the author's observations often showed greater proportional intensity for the violet as compared with the red than for intermediate colors, he considers it probable that the blue color of the air itself and a blue or violet due to the fluorescence of ozone or other components of the atmosphere are to be regarded as possible factors in the production of the color of the sky, altho the data upon this subject must be considered incomplete and inexact.

The following is the author's summary:

1. That while there is good reason for regarding the sky as a turbid medium, the experimental study of the spectrum of sky-light affords evidence of a distribution of intensities which cannot be altogether accounted for by the assumption of an atmosphere conforming to Rayleigh's formula nor of a turbid medium containing coarser particles.
2. That the illumination of the atmosphere by selectively reflected light from the surface of the earth and from cloud masses and mist modifies the character of the light from the sky to an extent which, while perhaps not readily discernible with the unaided eye, is definite and unmistakable when the sky is studied with the spectrophotometer.
3. That the deviation of the observed distribution of intensities recorded by several investigators indicates a blue absorption color of the air or, since the preponderance in the violet appears to be variable in amount, the existence of fluorescence of some unstable factor of the atmosphere, such as ozone, or both.

The results of observations on the percentage of polarization of skylight at the point of maximum polarization made by me in Washington at the Weather Bureau may be summarized as follows:

1. Since the observations were made on cloudless days, the sources of illumination of the sky are considered to be (a) the scattering of light by particles in the atmosphere whose diameters are small as compared with the wave-length of light, (b) the scattering of light by relatively large particles, and (c) the reflection of both sunlight and sky-light from the surface of the earth.
2. When the ground is covered with snow there is a marked decrease in the percentage of polarization, due to increased reflection from the surface of the earth.
3. There is a diurnal variation in the measured percentage of polarization, the minimum occurring at noon, with a gradual increase as the sun approaches the horizon, and a marked increase during the first few minutes of twilight following sunset, which may be attributed to relatively less reflection from the ground than from the particles in the atmosphere as the zenith distance of the sun increases.
4. The percentage of polarization decreases as the general atmospheric absorption increases, but apparently not by a simple law.

These results, which will be published in full in Vol. 2, Part 2, Bulletin of the Mount Weather Observatory, appear to be in accord with the summary given by Nichols.—H. H. K.

#### DUSTSTORMS IN TEXAS.

A correspondent calls attention to the fact that it is commonly believed in southern Texas, that whenever duststorms occur with high winds moving eastward across the plains, then the regions to the northward in Oklahoma and east Texas suffer from tornadoes. The following reply to this letter has been sent by the Acting Chief and sufficiently explains the reasons for this:

You will find by reference to daily weather maps issued by the Weather Bureau that the duststorms of western Texas occur in the south quadrants of well-marked low barometer areas, or general storms, the centers of which are moving eastward over the States to the northward. On January 27 and 28, the dates to which you refer, the center of a severe storm moved from Colorado eastward over Kansas. The westerly gales experienced in western and northern Texas obeyed the law of the cyclonic

circulation of winds. As air moisture is considered essential to the development of tornadoes, the dry air of the plains region does not present the tornadic elements that are found in more eastern districts. To this fact may be ascribed the greater frequency of local storms in eastern Texas and Oklahoma as compared to western portions of Texas.

It is proper to add to the above that, from the beginning of forecasting work, it has always been recognized that tornadoes occur in the southern quadrant of an area of low pressure, so that the forecast that "conditions are favorable for severe local storms" has frequently been published. Thunderstorms also occur most frequently in this quadrant, and so also the hot winds that injure the crops in the region between Texas and Iowa. It is scarcely proper to say that the duststorms of Texas literally change into tornadoes; but it is more proper to say that the conditions favoring the formation of duststorms in Texas will, as they advance eastward, favor the formation of tornadoes in the moister air farther east.—C. A.

#### THE AURORA POLARIS.

In a previous number of the MONTHLY WEATHER REVIEW<sup>1</sup> we have given a brief synopsis of the researches of Prof. Kristian Birkeland and Carl Störmer on the newest views with regard to the nature of the aurora borealis. We are now glad to announce the publication of the first part of two volumes by Birkeland, entitled "The Norwegian Aurora Polaris Expedition, 1902-3, Vol. I. On the cause of Magnetic Storms, and the Origin of Terrestrial Magnetism. First Section."

Being in English we doubt not that this volume will be read by many of the readers of the MONTHLY WEATHER REVIEW, and we can not resist the temptation to reproduce the following clear statement by the author, of the present state of his investigations.—C. A.

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By Prof. K. BIRKELAND.

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The knowledge gained, since 1896, in radio-activity has favored the view to which I gave expression in that year, namely, that magnetic disturbances on the earth, and aurora borealis, are due to corpuscular rays emitted by the sun.

During the period from 1896 to 1903, I carried out, in all, three expeditions to the polar regions for the purpose of procuring material that might further confirm this opinion. I have, moreover, during the last ten years, by the aid of numerous experimental investigations, endeavored to form a theory that should explain the origin of these phenomena. It is the results of these investigations that are recorded in this work, the first volume of which treats of terrestrial magnetic phenomena and earth currents, this section forming the first two-thirds of the volume. The second volume will treat of auroras and some results of meteorological observations made at our stations.

The leading principle that I have followed in this work has been to endeavor always to interpret the results of the worked-up terrestrial-magnetic observations, and the observations of auroras, upon the basis of my above-mentioned theory.

Thus, the magnetic storms, for instance, have been studied in such a manner that on the one hand we have formed from our observation-material a field of force which gives as complete a representation as possible of the perturbing forces ex-

<sup>1</sup>Monthly Weather Review, May, 1908, 36:129-131.

<sup>2</sup>This "First Section" is a Royal 4to., 315 pages, 139 figures, and 21 plates.

isting on the earth at the times under consideration. On the other hand, by experimental investigations with a little magnetic terrella in a large discharge-tube, and by mathematical analysis, we have endeavored to prove that a current of electric corpuscles from the sun would give rise to [corpuscular] precipitation upon the earth, the magnetic effect of which agrees well with the magnetic field of force that was found by the observations on the earth.

Altho our observation-material of magnetic storms was, I may safely say, the largest that has ever been dealt with at one time, it was deficient in certain points, as might well be expected.

We generally had at our disposal in 1902-3, magnetic registrations from twenty-five observatories scattered all over the world, among them being our four Norwegian stations on Iceland, Spitsbergen, Nova Zembla, and in Finmark.

We have, moreover, treated separately certain well-marked magnetic storms in 1882-83, from the observations in the reports of the international polar expeditions.

In addition to the deficiencies in our observation-material, there are also defects in the experimental and mathematical investigations; but, notwithstanding all this, the results are so satisfactory that I can hardly be mistaken in my belief that we are on the right road.

Besides making clear the origin of important terrestrial phenomena, the investigations give promise of the possibility of drawing, from the energy of the corpuscular precipitation on the earth, well-founded conclusions regarding the conditions on the sun.

The disintegration theory, which has proved of the greatest value in the explanation of the radio-active phenomena, may possibly also afford sufficient explanation as to the origin of the sun's heat. The energy of the corpuscular precipitation that takes place in the polar regions during magnetic storms seems, indeed, to indicate a disintegration process in the sun of such magnitude, that it may possibly clear up this most important question in solar physics.

Future researches in the paths here entered upon, which I believe will lead to the solution of some of the most attractive scientific problems of our age, e. g., the origin of terrestrial magnetism, and the origin of the sun's heat, may be carried out upon a far wider basis than I have been able to employ without making the expenses connected therewith too great a deterrent.

In 1902-3 I had the great good fortune to have twenty-five observatories with me; but on a future occasion it will be necessary to have double the number.

We should then have to send out small expeditions with, say, ten stations suitably distributed about each of the magnetic poles, and make sure of getting magnetic registrations for the same period from all the observatories in the world.

As the position of the stations, within certain limits, may be chosen with tolerable freedom, the end would be best attained by accompanying whalers, or, as I once had to do, equipping such vessels one's self for certain places.

The mathematical investigations which, together with my experiments, are intended to make clear the movement of electric corpuscles from the sun to the earth, have been carried out with a perseverance and ingenuity worthy of all admiration by my friend Professor Störmer, who will publish the complete results of his investigations in a special part of the present work. These results, however, will be known to some extent from the papers he has already published.

The present section treats of a series of magnetic perturbations from the material from 1902 and 1903. For each separate perturbation, the magnetograms from the various observatories are arranged one after another in plates, so that the course of the perturbation can be followed from station to station.

The character of the curves in low latitudes is generally quiet, without sharp serrations. A slow variation is found in the conditions from place to place, and the deflections in the curves take place almost simultaneously over large portions of the globe.

At the polar stations, on the contrary, the curves are of an exceedingly disturbed character and very jagged, and show very great variation from place to place in the conditions during powerful storms. At these stations the perturbing forces are as a rule from ten to twenty times more powerful than they are even  $20^\circ$  farther south. The great deflections may frequently be followed from place to place, but in this region they do not always occur simultaneously; even at closely adjacent stations a distinct phase-displacement in these deflections is continually to be found. It would thus appear that in lower latitudes the current-systems that were in operation must be comparatively distant; whereas in the north they come into the immediate vicinity of the stations, thereby giving a more local character to the perturbations there. The movement of the systems can be followed by the phase-displacement in the deflections.

The simplest storms are studied first. They are called *elementary* storms, and are divided into five classes, namely, the positive and negative polar, the positive and negative equatorial, and the cyclo median storms.

In the next place it is shown that the ordinary complex magnetic storms may be regarded as composed of various kinds of elementary storms. The distribution of force on the earth during the above-mentioned storms is illustrated on charts by "current-arrows" whose length is proportional to the magnitude of the horizontal component of the perturbing force, and which give the direction of a horizontal electric current above each place, such as would there have produced the same magnetic effect as that actually found.

These "current-arrows," however, are no indication of the existence of such currents everywhere; they are only employed for the purpose of giving a clear general idea of the field of force in the perturbations, independent of all hypothesis.

Two of the most typical elementary fields are here reproduced (omitted). One represents the typical field of a negative polar elementary storm, the other the field in a positive equatorial storm. The first field can be explained, very simply and naturally, as the effect of corpuscular currents moving in toward the earth in the arctic regions—in this case in the auroral zone in the district surrounding Iceland—after which they turn round in an easterly direction (assuming the rays to be negative), and once more disappear into space. A current-system such as this will have approximately the same effect as a linear galvanic current consisting of two vertical current-portions connected by a horizontal portion; and it is shown that even a quantitative harmony may be attained between the field formed by such a current and the polar elementary fields that have been found. When a current-system such as this moves away, the surrounding field, we must assume, will move in the same direction. This moving of the fields is continually found in low latitudes; and in cases in which the motion of the polar system can at the same time be followed in the manner previously indicated, it is proved that they agree most exactly with one another.

The second field is explained naturally by the existence of current-systems that are formed outside the earth, more or less in the plane of the magnetic equator. The changes in the positive equatorial field are apparent in the curves, from characteristic serrations found simultaneously at all stations.

Finally, the above five types of elementary storms have proved sufficient, as regards the perturbations here described, to account for all the fields that have been formed, even during the most complex storms.

In the terrella-experiments, conditions were found that seem to confirm the correctness of this view of the cause of the magnetic perturbations; and to some extent the harmony between the results of the observations and the experiments is striking. The results of the mathematical investigations also give powerful support to this view. In connection with the polar elementary types, for instance, it may be stated that a drawing-in of rays takes place just in a zone answering to the auroral zone; and here the rays descend more or less vertically upon the terrella, and then glance past it as they turn and once more disappear into space. Further, as to the equatorial types a luminous ring is formed under certain conditions in the experiments, this ring consisting of rays that move round the terrella in the plane of its magnetic equator; and there are also found systems of rays that turn round before reaching the terrella, in just such a manner that its effect would correspond to the positive equatorial field.

Two figures representing terrella-experiments are reproduced. One is a series of eight photographs, representing an experiment in which photographs were taken from eight different points of view. The position of the terrella answers to the winter solstice and to 6 a. m. at the magnetic north pole. The photographs have been taken in such a manner as to show successively the afternoon side, the night side, and the morning side of the terrella, the cathode in the discharge-tube being supposed to represent the sun. It will be seen how rings, or rather spirals of light are formed round the magnetic poles of the terrella, and how the rays descend in zones that evidently answer to the auroral zones on the earth.

The second figure shows how the rays move in space round the terrella, and how they are drawn in more or less vertically and concentrated in the polar zones.

Finally, it is shown how the polar systems to some extent follow the sun in its diurnal motion, and how this circumstance varies when the height of the sun above the magnetic equator alters greatly. The most powerful negative polar storms originate, as a rule, on the night side of the earth, the positive polar storms generally on the afternoon side.

#### A STUDY OF OVERCAST SKIES.

By Prof. E. L. NICHOLS, Cornell University. Dated June, 1908.

[Reprinted from *Physical Review*, 1908, 28: 122-131.]

In two recent communications I have described the results of certain measurements of the visible spectrum of the light from the sky<sup>1</sup> and have made comparisons between the spectrum of daylight and that of various artificial sources of illumination.<sup>2</sup> In the present paper the spectrum of the light of overcast skies is more particularly considered in its relations to the spectra obtained from the cloudless sky and from skies in intermediate stages.

As in the measurements already described the instrument used was a spectrophotometer of the Lummer-Brodhun type so arranged that one collimator pointed to the zenith while the other, which was horizontal, received the light from a comparison source of nearly constant intensity and composition. This comparison source was an acetylene flame. Measurements were made thruout the visible spectrum from the extreme red at  $0.74\mu$  to the extreme violet at  $0.38\mu$ , thus including in the observations two regions lying close to the boundaries of the spectrum which had hitherto been comparatively neglected. The results obtained, as in the previous papers just referred to, are presented in the form of curves in which abscissas are wave-lengths and ordinates give the brightness of the spectrum of skylight in terms of the brightness of the corresponding region in the spectrum of the acetylene flame. The scale

adopted is entirely arbitrary. The brightness of the comparison spectrum was adjusted to a convenient intensity by the interposition of a diaphragm in front of the flame and of a milk glass screen of neutral tint, the nonselective character of the transmitting power of which had been ascertained by careful observation. Altho many studies of the quality of the light from clear skies have been made, generally for the purpose of testing Rayleigh's theory, but little attention has been given to the light of clouded skies. So far as I am aware, indeed, the only definite spectrophotometric data are those published by Crova in the course of his extended and systematic observations on the skies at Montpellier in France.<sup>3</sup>

The results to be described in this paper were made during a vacation journey in Europe in 1907.

Measurements of the spectrum of the light from the zenith taken at times when the sky was completely overcast, gave curves notable for their simplicity and for their similarity to one another. The type of these curves is sufficiently represented in fig. 1 where the curve *V* is for an overcast sky studied in Vienna in June, 1907, and *Z* represents the character of the

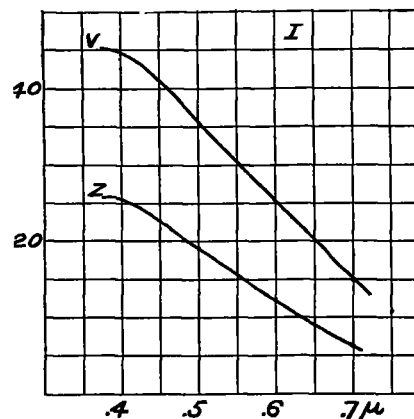


FIG. 1.

light obtained from a similar sky measured at Zell am See, Austria, in July of that year. The former curve was taken just before noon on a rather bright but completely cloudy day, the latter about 6 p. m. when the sky was heavily overcast and threatening rain. While these two skies differ in brightness approximately in the ratio of one to two they indicate remarkable similarity as to the composition of the light coming from the clouds.

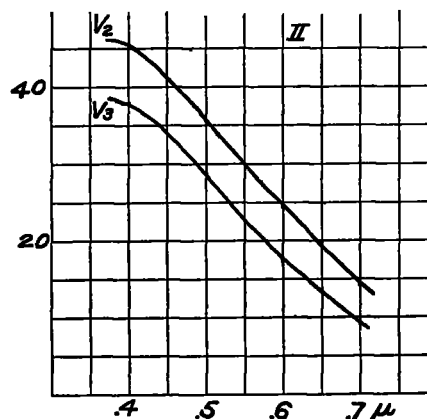


FIG. 2.

It was noted by Crova in the course of his investigation that overcast skies differ but little in composition from many cloudless skies. This observation is verified by a comparison of the

<sup>3</sup> Crova, *Annales de Chimie et de Physique* (6), XX., p. 480.

<sup>1</sup> Nichols, *Phys. Rev.*, Vol. XXVI., p. 497. [See above p. 15.]

<sup>2</sup> Nichols, *Transactions of the Illuminating Engineering Society*, Vol. III., p. 301.